Ocean Acoustic Observatories: Data Analysis and Interpretation

A Collaborative Project Conducted by

Peter F. Worcester
Scripps Institution of Oceanography, University of California at San Diego
La Jolla, CA 92093-0225
phone: (619) 534-4688 fax: (619) 534-6251 email: pworcester@ucsd.edu

Award: N00014-95-1-0589

James A. Mercer and Robert C. Spindel
Applied Physics Laboratory, College of Ocean and Fishery Sciences
University of Washington
Seattle, WA 98105-6698
phone: (206) 543-1361 fax: (206) 543-678 email: mercer@apl.washington.edu
phone: (206) 543-1310 fax: (206) 543-3521 email: spindel@apl.washington.edu

Award #: N00014-95-1-0800

LONG-TERM GOAL

The ultimate limits to the coherence of long-range acoustic transmissions are imposed by ocean processes, including internal waves, mesoscale variability, interior ocean boundaries (fronts), and bathymetric scattering. An understanding of the effects of these processes on acoustic signals is crucial to the use of acoustic remote sensing methods for a broad range of purposes, including undersea surveillance, ocean acoustic tomography, and large-scale acoustic thermometry. The long-term goals of this research are to enhance our understanding of the ocean processes that ultimately determine the limits of useful long-range acoustic transmissions and to improve our capability to both generate and detect very long-range transmissions.

OBJECTIVES

Theoretical considerations suggest that acoustic scattering due to internal-wave-induced sound-speed perturbations will be small at very-low frequencies, i.e., below about 30 Hz, even at multi-megameter ranges. The objective of this research is to understand the frequency dependence of scattering from internal waves and other oceanographic features at multi-megameter ranges.

APPROACH

A short term transmission test, the Alternate Source Test (AST), was conducted during June-July 1996 to compare broadband transmissions at 28 Hz and 84 Hz (phase-locked coherent signals, each with a 10-Hz bandwidth). An HLF-6A acoustic source was suspended from shipboard near Pioneer Seamount off central California and transmitted to two autonomous vertical line array (AVLA) receivers and to ten horizontal line array (HLA) receivers, at ranges from 150 km to about 5 Mm. The combination of temporal and spatial resolution makes it possible to isolate individual rays and, at the AVLA receivers, low order modes, in order to elucidate the basic scattering physics. The data collected on the AVLA and HLA receivers will be used to compare a variety of measures of the scattering at the two frequencies, including travel time variance, and spread, scintillation index, coherences in time, frequency, and space, emphasizing the unique capabilities of the AVLAs to provide information on vertical coherence and modal structure and of the HLAs to provide information on the horizontal coherence and spatial variability of the scattering. The computed statistics will be compared with

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **Ocean Acoustic Observatories: Data Analysis and Interpretation**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of California at San Diego,Scripps Institution of Oceanography,La Jolla,CA,92093**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**3**	

theoretical predictions. SIO investigators will play the leading role in analyzing the data from the AVLA receivers, while APL/UW investigators will take the lead in analyzing the data from the HLA receivers.

WORK COMPLETED

Analysis of the data continued throughout FY98. Signal processing of the dual-frequency receptions has been completed and routine clock and mooring motion corrections have been applied to the AVLA data (receivers at ranges of approximately 3500 km and 5100 km). Data from the AVLAs and two of the HLAs (at approximately 150 and 700 km) have been analyzed.

The dual-frequency AVLA data have been used to test a modified vertical beamformer that explicitly takes account of the depth dependence of the sound-speed profile, using a local WKBJ approximation. The modified beamformer, called a turning-point filter, permits a uniform treatment of the arrival pattern, from the early ray-like arrivals to the late mode-like arrivals.

RESULTS

Results indicate that internal-wave-induced acoustic scattering is less important at 28 Hz than at 84 Hz.

Processing of vertical line array data shows that the 28-Hz data has a more stable arrival pattern compared to the 84-Hz data. This comparison holds for both the early ray arrivals and late mode arrivals. Interpretation of the arrival pattern via a "turning point filter" has allowed a unified framework for comparison of both regions. In simulations without internal waves the turning-point filter collapses the acoustic arrival pattern at low vertical angles into a single energy-containing curve in vertical arrival angle – travel time coordinates, where vertical arrival angle can be interpreted in terms of ray and mode turning point depths. Using real data the arrival pattern does not collapse at low angles, however, suggesting that internal-wave-induced scattering is still non-negligible even at 28 Hz. A paper describing the turning point filter results is in preparation.

The horizontal line array data obtained on a receiver below the sound channel approximately 700 km west of the source gave rms travel time fluctuations for one resolved "ray" arrival of 7.8 ms at 28 Hz and 10.2 ms at 84 Hz, in the range of expected values. However the predicted ray arrivals turn above the receiver, and we do not understand the associated propagation; explanations for this behavior (also observed in other experiments with different ranges and frequencies) is being sought. The scintillation index is approximately 0.11 at 28 Hz and 0.65 at 84 Hz, indicating much more stable amplitudes at the lower frequency. Travel time spread is near zero for both frequencies. For the 150-km receiver there were no single resolved ray arrivals; the arrival peak analyzed had two predicted ray arrivals separated by 15 ms. In this case the rms travel time fluctuations were much large then one would expect for a single ray at this range because of interference effects (order 14 ms for both frequencies compared to a few milliseconds expected for a single ray). The scintillation index, though was 0.26 at 28 Hz and 0.64 at 84 Hz. While these scintillation estimates are contaminated by the two rays interfering with one another, the trend also reflects the improvement (less fluctuation) at lower frequency.

The path integral theory of internal-wave-induced scattering in the ocean predicts that travel time bias is proportional to the logarithm of the acoustic frequency. The dual frequency AST data should therefore give information on the relative bias at the two frequencies. In preliminary calculations using the AVLA data (Hawaii AVLA at 3500 km), the differences in travel times for simultaneous transmissions at 28 Hz and 84 Hz are found to be of order 50 ms. For comparison, simulations by Colosi and Flatté give biases that are less than 50 ms at 3 Mm range. For the two HLAs, the difference in travel time between the two frequencies is 18 ms (150 km) and 31 ms (700 km), with the 28 Hz signal arriving later than the 84

Hz signal. At this point we can only say that the measurements are roughly in agreement with predictions; a more quantitative comparison is in progress.

IMPACT/APPLICATIONS

Existing systems, whether active or passive, are not anywhere near the limits of what can be done in underwater acoustics. A full understanding of the ultimate limits to acoustic coherence at long range in the ocean is essential to the design of any acoustic system for remote sensing of the ocean interior, whether it be for measurement of ocean temperatures, tracking of whales, detection of submarines, or the study of volcanic processes at mid-ocean ridges. At the conclusion of our analyses we expect to have a much fuller understanding of the frequency dependence of acoustic scattering from ocean features at multi-megameter ranges, and of the potential for exploiting the anticipated reduction in scattering, and corresponding increase in coherence, at very low frequencies.

TRANSITIONS

None.

RELATED PROJECTS

This work has been closely coordinated with, and partly supported by, the Acoustic Thermometry of Ocean Climate (ATOC) project and the ONR North Pacific Acoustic Laboratory (NPAL) project. We continue to collaborate very closely with J. Colosi (WHOI) and S. Flatté (UCSC).